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THIS DOCUMENT CONTAINS 3 MAIN SECTIONS: (1) PRIMARY PRODUCTIVITY ESTIMATES IN LOWER DERBY AND LADORA LAKES; (2) FISH SURVIVAL EXPERIMENT, NORTH BOG POND; (3) THE PRINCIPLES OF LAKE BED AERATION. ALSO INCLUDED IS A PERIODICAL ARTICLE: BROWN, M.F. "AERATION," FISHING FACTS, APRIL 1975, PP. 105-113. THIS REPORT LEADS TO A POSSIBLE MEANS FOR REDUCING THE AMOUNT OF CHLORINATED HYDROCARBONS IN THE RMA LAKES. BY REVERSING THE EUTROPHICATION PROCESS IN THE ARSENAL LAKES, THIS SHOULD REDUCE THE SEVERE AQUATIC WEED GROWTHS, IMPROVE THE GENERAL CONDITION OF THE FISHERIES AND BREAKDOWN OTHER UNWANTED ORGANICS. PROPOSED IS THE INSTALLATION OF FOUR LAKE BED AERATORS.

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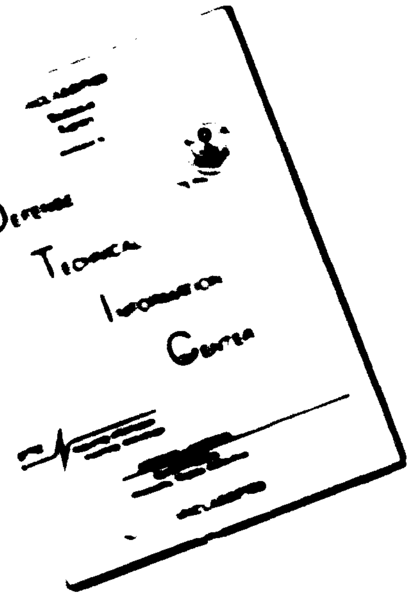

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SPECIAL REPORTS SECTION

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SPECIAL REPORTS SECTION

Primary Productivity Estimates

in Lower Derby and Ladora Lakes

Primary production is the weight of new organic matter created by photosynthesis, or the energy represented by the process of creating the new organic matter (Westlake, 1966). Primary productivity is the rate of primary production.

The light and dark bottle technique was used for estimating primary productivity in Lower Derby and Ladora lakes. One 1-liter water sample was taken in each light and dark polyethylene plastic sampling bottle for each lake. Initial dissolved oxygen readings were taken and the bottles were suspended near the surface for a period of 24 hours. Samples were taken near the surface due to lack of time and available equipment at sampling time. Gross and net photosynthesis rates are estimated according to methods given by Reed (1968).

Gross photosynthesis = LB - DB*
Net photosynthesis = LB - initial
Respiration = initial - DB
*LB = Light bottle; DB = Dark bottle

Lower Derby Reservoir	Ladora Lake
Initial O_2 = 7.70ppm	Initial O_2 = 10.00ppm
LB O_2 = 7.85ppm	LB O_2 = 9.13ppm
DB O_2 = 7.10ppm	DB O_2 = 8.17ppm

	Lower Derby Reservoir	Lake Ladora
Gross Photosynthesis	0.75ppm	0.96ppm
Net Photosynthesis	0.15ppm	-0.37ppm
Respiration	0.60ppm	1.83ppm

Gross photosynthesis expressed as milligrams of carbon assimilated (mg - C_{ass}) is found by dividing the gross photosynthesis value (GP) by the gram atomic weight of oxygen (GW-O) and multiplying this quotient by the quotient of the gram atomic weight of carbon (GW-C) divided by the photosynthetic quotient (PQ) (Reed, 1968).

$$\text{mg} - C_{ass} = (GP/GW\text{-}O) \quad X \quad (GW\text{-}C/PQ)$$

$$PQ = \frac{\text{no. molecules } O_2 \text{ liberated}}{\text{no. molecules } CO_2 \text{ assimilated}}$$

$$= \frac{(\text{Net photosynthesis})(\text{Gram molecular weight of } O_2)}{(\text{Gross photosynthesis})(\text{Gram molecular weight of } CO_2)}$$

	Lower Derby Reservoir	Ladora Lake
mg carbon assimilated (in mg/l)	4.0 mgC/l	-1.09mgC/l

Discussion

The results for Lake Ladora are obviously invalid due to the negative value of "carbon assimilated" obtained. This negative value only indicates that the sample was taken too close to dense weed beds where the diurnal CO_2 - O_2 cycle fluctuates widely and sporadically, depending on light, temperature, pH conditions and vegetative type. The aquatic weed beds were too dense in Lake Ladora to obtain unbiased dissolved oxygen readings at any location in the lake at sampling time.

The dissolved oxygen readings for Lower Derby were not taken near any dense aquatic vegetation and provide a more reasonable estimate of carbon assimilated. Since the Lake Ladora estimates have been invalidated, no data is available to compare with the Lower Derby results. The 4.0 mgC/l figure obtained, however, represents a substantial assimilation of carbon by primary producers and is concurrent with fish, plankton and plant production observed in Lower Derby.

Fish Survival Experiment, North Bog Pond

While gill netting and sampling North Bog Pond for fish populations and other aquatic organisms it became apparent that the bog water was probably toxic to fish life. No fish were netted or observed during the sampling period (from 8-1-77 to 10-15-77). The only vertebrate population collected were the amphibians (Necturus maculosus). A sizeable population of these water dogs exists in North Bog

To determine the ability of the North Bog water to support fish life several tests were conducted with the most resistant fish species available on Rocky Mountain Arsenal. Black bullhead (Ictalurus melas) were used as test animals for each experiment and were transferred from Lower Derby and Rod and Gun Club Pond to the North Bog.

Test Number One

In test number one three black bullheads were placed in live-box no. 1 and two black bullheads were placed in live-box no. 2. Minnow traps were used to decrease activity of the fish. The small confinement space within the live-boxes reduced metabolic activity of the fish. Confinement will usually increase time limits of mortality in lethal dosage tests. Test number one was conducted starting 9-27-77 and concluded on 10-3-77.

Test Number Two

In test no.2 ten black bullhead were placed in two 2'X2'X4' live-boxes, to rule out differences in mortality due to confinement as in test no. 1 and differences in mortality from variable metoblic rates. Higher metabolic rates were expected in the larger live-boxes where fish could move about freely. Five fish were placed in each live-box and suspended in the water. Test no. 2 began 10-6-77 and terminated 10-10-77.

Test Results

In test no. 1 no mortality occurred in the live-boxes within 120 hours. At 144 hours three black bullhead had died. The two remaining fish were very weak and lethargic. Close observation revealed gill anemia, skin discoloration, capillary dilatation and hemorrhage. Edema of the dorsal musculature and vent was also prevelent on the remaining live fish. A total mortality occurred after seven days or 168 hours. The cummulative effect of the conditions described above apparently resulted in the death of the fish.

Test no. 2 was conducted on 10-6-77 in which a cold snap had cooled the bog water considerably. Within 48 hours the ten test fish, five in each live-box, were lethargic and weak. On 10-8-77 50% of the bullheads had died, and by 10-10-77 total mortality had occurred

in 120 hours. The decreased time of mortality over test no.1 was attributed to increased metabolic rates of the fish in larger live-boxes and a possible increase in toxicity of the unknown toxicant at lower water temperatures. Due to the rapid initial mortality it is believed that whatever toxicant is present it's LD_{50} on black bullhead may decrease sharply with a decline in water temperature.

Discussion

There appears to be two or three factors which contribute to the toxicity of the bog water to fish. It could be stated that the toxicity of the water must be minimal due to the abundance of aquatic insect fauna and the fact that North Bog supports a large population of amphibians (Neturus maculosus). These organisms could surely not survive if the toxicity of the water was acute.

Due to the difference in gill morphology of the amphibians (chemical exchanges between the gill water interface) they are apparently more resistant to the toxicants or do not accummulate it as rapidly as most fish species. Low oxygen concentrations and bluegreen algae blooms may also contribute to water toxicity. Several blue-green algae blooms were noted during the sampling period. Amphibians are known to be more resistant to lower oxygen concentrations than most fish species and this could be one factor contributing to their success.

A substantial amount of background research on chemical contaminates is needed to define a specific study program for the North Bog. A detailed study would be required to define the parameters contributing to toxicity of the water in North Bog to fish life. As stated previously it appears that toxicity to fish is marginal due to the abundant production of littoral insect fauna and the thriving amphibian population.

It may be possible to support fish life in Bog Pond with a minimal amount of capital expenditure. Tests on water quality, dissolved oxygen values and chemical contaminate levels would be needed to determine the feasibility of lake bed aeration as a possible solution to this problem. Lake bed aeration has been found to be effective in reducing natural organic pollutants, such as organic waste products (Browne, Mervin F.,1975). Specifically, lake bed aeration can reduce nitrogen in the form of ammonia, lower iron and manganese levels, decrease potentially toxic bluegreen algae, reduce nitrogen and phosphates and increase benthic breakdown of organics by stepping up aerobic bacterial decomposition.

We propose a feasibility study to determine the effects of lake bed aeration on the reduction of organic pollutants present in the Rocky Mountain Arsenal lakes. North Bog Pond would be an ideal initial study pond due to its small size, availability of electricity for operation of the aerators and the degree of simplicity in this aquatic community. Solving the problem of fish survival in North Bog could be studied concurrently.

Proposal For Lake Bed Aeration

The fate and behavior of organic pesticides in the aquatic environment has concerned scientists almost from the time of their conception. Of greatest concern are the chlorinated hydrocarbons, due to their persistence in aquatic ecosystems. Chlorinated hydrocarbons in lentic ecosystems of greatest importance are dieldrin, aldrin, endrin, isodrin and DDD; derivitives of DDT.

To elucidate the fate of these pesticides in the aquatic environment at least three cases must be considered:

1. Dissappearance of insecticide from the water by evaporation and tranpiration of the plants at the air water interface without chemical change to the insecticide.

2. Influence of sunlight, oxygen, suspended particulate matter in the water, and photo-oxidation, with chemical change.

3. Metabolism in living organisms (biodegradation) caused by enzymatical activity.

The purpose of this report is to suggest a possible means of reducing the amounts of organic pesticides in the aquatic ecosystems on Rocky Mountain Arsenal. Although this appears to be a task of monumental proportions, current literature suggests a possible method in the reduction of chlorinated hydrocarbons as well as other less persistent organic contaminants.

It is generally accepted by most investigators that the persistance of the pesticide DDT may be slowly degraded by the action of light and air (1,2). Photo-oxidation of DDT produces benzoic acids, aromatic ketones and chlorinated phenols. DDE also undergoes photo-oxidation to give dichlorofluorene derivatives. The photo-oxidation of DDT and DDE are thought to be brought about by the reductive loss of chlorine by fragmentation. The sequence of reactions in the photo-oxidation process are postulated by Mosier (3). He postulates eight reactive processes in the breakdown of chlorinated hydrocarbons in the presence of oxygen. Many studies have shown that concentrations of DDT'S in aquatic systems dissappears rapidly from the open water in a relatively short time (4). Original concentrations of chlorinated hydrocarbons decline rapidly from the water, but are deposited in the bottom muds (benthos) of lake systems. This rapid dissappearance in water is attributed to bio accumulation by flocculant bacteria, zoo and phytoplankton and particulate matter settling out of the water column of lakes. This material carries these pesticides to the lake bottom where they are deposited in the sediments. The bioaccumulative factor of bottom organic sediments is described as very great. Chlorinated hydrocarbons have a great affinity for organic matter

on the benthos. These chlorinated hydrocarbon particulates that have accumulated on the bottom sediments are the primary source of contamination in the aquatic environment and pose the greatest challenge for cleanup. Chlorinated hydrocarbons are adsorbed onto the organic substrate and usually accumulate within the first few centimeters of the bottom sediments.

Shin (5,6) found that DDT adsorbtion in soil increased with the stage of humification of soil organic matter. This would lead one to believe that adsorbtion in aquatic soil systems must be high. Aldrin and dieldrin were adsorbed from aqueous soil particulate matter and volatilized from aqueous systems (5), showing that adsorbtion and volatilization are improtant processes in the disappearing of these compounds from aquatic soil systems. Adsorbtion of aldrin, dieldrin and endrin is directly related to the organic content of the soil (8,9,10). Higher levels of organic matter in soils increases persistence of aldrin in the soil, decreases the adsorbtion of dieldrin and endrin by erops and decreases the volatilizing of the compounds from the soil (5,11).

As indicated above, floc-forming bacteria are an important factor in the sedimentation of chlorinated hydrocarbons from the water column. Flocculent bacteria also adsorb other microparticulates which represents a mechanism of removal of suspended particulates with subsequent sediment formation and decrease in overall turbidity.(12,15). In adsorbtion experiments with aldrin, Leshniowsky, et al (1970), identified one floc-forming bacteria that adsorbed aldrin as Bacillus and one other was tentatively identified as either Flavobacterium or Protaminobacter. Thirty-three aerobic bacteria isolates were tested in six different growth media in these experiments and Leshniowsky, et al , (1970) report that nineteen formed flocs in at least one medium and ten formed flocs in two or more of the media.

Adsorbtion rates for aldrin were reported to be rapid and concentration levels by the bacteria were high. Adsorbtion of all the aldrin added to the suspensions (1×10^{-6}g/ ml. or 1 p.p.m. aldrin) was adsorbed by the bacteria within twenty minutes of initial exposure. The concentration factor was estimated as 625 to 1 when 0.041 g of flocculent bacteria adsorbed aldrin in 25 g of water. Flocculent aerobes, amoung other types, are abundant in lentic environments and their numbers will increase significantly when exposed to increased oxygen levels provided by aeration.

Other bacteria have been identified in similar investigations (13) as important in the decomposition of dieldrin and certain hydrocarbon herbicides(14) in soil. Matsumura and Boush(1967) report that bacteria belonging to the genera Bacillus, Pseudomonas and Trichoderma were responsible for the conversion of 1

to 6 percent of dieldrin to water soluble metabolites within a thirty day test period. It is interesting that six distinct species of Pseudomonas sp. are widely distributed in lake water (along with species of Flavobacterium, Bacillus and others (15): are "highly aerobic and capable of utilizing organic nutrients" (16). Matsumura and Bousch (1967) also point out that certain bacteria, e.g. Trichoderma viride produce numerous variants, and that these subspecies are the organisms responsible for the decomposition of specific contaminants (in this case, dieldrin). It is reasonable to assume that the bacteria endemic to the Rocky Mountain Arsenal lakes have had ample exposure time to the contaminants under consideration to develop variants capable of pesticide decomposition.

It is not understood by the authors how sulfur dioxide can be a problem in an aquatic environment, unless significantly large amounts are discharged into the lake system. SO_2 in water readily forms sulfurous acid (H_2SO_3) a weak acid, according to the equation(17):

$$SO_2 + H_2O \rightleftharpoons H_2SO_3$$

Sulfurous acid will then take up oxygen slowly to form sulfuric acid (H_2SO_4), a strong acid (18):

$$2H_2SO_3 + O_2 \longrightarrow 2H_2SO_4$$

Sulfuric acid, however, is highly soluble in water and undergoes 100 % ionization as follows (17):

$$H_2SO_4 + H_2O \xrightarrow{100\ \%} H_3O^+ + HSO_4^-$$

The fate of the hydronium ion H_3O^+ or ($H_2O \cdot H^+$) is uncertain. The bisulfate ion (HSO_4^-) undergoes further ionization in water:

$$HSO_4^- + H_2O \longrightarrow H_3O^+ + SO_4^=$$

The sulfate (SO_4) can then be reduced by anaerobic bacteria to hydrogen sulfide (H_2S) and released to the air as a gas by natural processes. This is the so called rotten egg gas that is often present where large amounts of organic matter have accumulated. Hydrogen sulfide elimination is rapid with lake bed aeration.

Insufficient time has been available to study the decomposition mechanisms of sulphone, oxylate, dithane, isodrin or DIMP. Since DIMP (Di-iso-methyl-phosphonate) is an organic compound, contains a phosphate component and has relatively high vapor pressure (as judged by its ease of volatilization in aggitated water) , it is assumed by the authors that breakdown by the same aerobic mechanisms as described for the chlorinated hydrocarbons is likely.

Proposal

The above discussion leads to a possible means for reducing the amount of chlorinated hydrocarbons in the Rocky Mountain Arsenal lakes. The other benefits of lake bed aeration are covered in the main report and are detailed in a brochure following this report. By reversing the eutrophication process in the Arsenal lakes this should reduce the severe aquatic weed growths, improve the general condition of the fisheries and breakdown other unwanted organics.

Rocky Mountain Fisheries proposes the installation of four lake bed aerators as a pilot program to determine the feasibility of chlorinated hydrocarbon and other organics breakdown in the Arsenal lakes. We propose installation of one aerator each, in Lake Mary, Ladora, Lower Derby and North Bog Pond. Electricity is readily available in all of these areas for ease of hookup. This capital expenditure is very slight compared to the benefits of lake bed aeration. Samples could be taken periodically to determine any change in chlorinated hydrocarbon and other chemical substrate concentrations.

The cost of one lake bed aerator installed, if electricity is on site is \$ 500.00 to \$ 600.00. One hundred-ten volt, 15 amp. power hookup is required.

Literature Cited

Browne, M. F. (1974) , Aeration An Answer For Some Sick Lakes. Fishing Facts; Apr., 1974.

Reed, E. B. (1968). Handbook Of Limnological Methods. Unpub; 127 P.

Westlake, D. F. (1966). Primary Productivity of Aquatic Macrophytes. C. R. Goldman, ed. Univ. Of Calif. Press, Berkely pp. 229-248.

1. Plimmer, J. R. (1970). Photooxidation of DDT and DDE. Science 167: 67-9: Jan 2, 1970.
2. Gunther, F. J., Chemical Education 22: 238 (1945).
3. Mosier, W. D. Guenzi, Miller: Science 164: 1038. (1969).
4. Hamelink, J. L. (1975). DDE and Lindane In A Large Scale Lentic Ecosystem. Transactions Of The American Fisheries Society. (pp. 124-133).
5. Gould, R. F. (1972). Fate of Organic Pesticides In The Aquatic Environment. Advances in Chemistry Series. Amer. Chemical Society, Wash., D. C.
6. Shin, Y. O., Chodan, J. J., Wolcott, A. R. Journal of Agriculture and Food Chemistry 18; 1129 (1970).
7. Wiese, I. H. , South African Journal of Agricul. and Food Science. 7; 823 (1964).
8. Harris, C. R., Sans, W. W. (1967). Journal of Economic Agricul. and Food Chemistry 15; 861.
9. Beall, M. L., Jr., Nash, R. G. (1969) Agronomy Journal 61: 571.
10. Edwards, C. A. (1957). Journal of Economic Entomology 50: 622.
11. Leshniowsky, W. O., Dugan, P.R., Pfister, R. M., Frea, J. I., Randles, C. I. Aldrin: Removal From Lake Water by Flocculent Bacteria. Science 169: 993-5 Sept. 4, 1970.
12. Harris, C. R., Sans, W. W. (1969). Pesticide Monitor Journal 3: 181.
13. Matsumura, F., Boush, G. M. Dieldrin: Degradation by Soil Microorganisms. Science 169: 959-61.

14. Alexander, M. (1964). Microbiology of Pesticides and Related Hydrocarbons. Principles and Applications in Aquatic Microbiology, Heukelekian and Dondero, editors. John Wiley and Sons, Inc. New York.

15. Rheinheimer, G. (1974). Aquatic Microbiology, second ed. John Wiley and Sons, Inc. New York.

16. Carpender, F. L. (1967). Microbiology, second ed. W. B. Saunders Co., Phila.

17. Lee, G. L., Van Orden, H. O. (1965). General Chemistry, second edition. W. B. Saunders Co., Phila.

18. Brownlee, R. B., Fuller, R. W., Hancoek, W. J., Sohon, M. D., Whitsit, J. E. (1950). Elements of Chemistry. Allyn and Bacon, New York.

THE PRINCIPLES OF LAKE BED AERATION

AERATION

Why it's needed.

How it works.

What it does for lakes, farm ponds, reservoirs, flowages and factory and feedlot run-off and effluent lagoons

by Dr. MERVIN F. BROWNE

EDITOR'S NOTE

Sure, many of our fishing waters have become polluted and others are getting there. Yes, it will cost billions to clean it up. Nothing new about that, is there? Well, we wouldn't waste your time and our space simply to write another "sick lake" story. We all know that it will take years — and billions — to hunt down every source of water pollution and correct it. (It will be a long, hard struggle, and we may not even win.)

BUT, a relatively inexpensive piece of equipment has come along which costs considerably less than $500 and which is available to anyone with the desire to do something about their "sick waters". One unit will handle a lake or pond up to 20 acres. Resort owners can use two or three units in front of their places to help eliminate fouled swimming beaches and provide better fishing right out in front of the place. Individual lake home owners can install their own unit out in front of their place, and if a number of adjoining property owners do likewise, a whole section of the lake can be improved.

The piece of equipment that can do all this is the Lake Bed Aerator, which acts to add natural dissolved oxygen to water to replace the dissolved oxygen which pollution and eutrophication has stolen from it. Fishing waters with sufficient dissolved oxygen means more and better fish who multiply better, fight better, and taste better.

Our interest in the Lake Bed Aerator lies in the fact that it is relatively inexpensive and represents something that YOU can use to help your own fishing waters, if they are "sick". It is not a "cure-all", and it won't clean up an entire reservoir that's 90 miles long . . . but it may work real "magic" for you wherever you install it.

An article in Fishing Facts of March 1974 ("Hope For Troubled Waters"), resulted in inquiries from and installations of lake bed aerators in all parts of the country. Every report that has reached us about their performance has been positive, most of them glowing. Those who installed Lake Bed Aerators are excited about them, so are we. It's a simple, practical piece of equipment for the do-it-yourselfer, for a business establishment, or for a town or municipality.

This article, coming 13 months after the "Hope For Troubled Waters" story, was written at our request.

We think there are many of our readers — and their friends — who might wish to give careful CONSIDERATION to the purchase and usage of such equipment. (We don't try to tell you what to think or what to buy, but we do try to give you information that will assist you in arriving at your own decisions.)

Dr. Mervin F. Browne, author of this article is president of Kembro, Incorporated in Mequon, Wisconsin.

Known as "Doc" Browne by his fishing friends, he graduated from the University of Illinois in Chemistry and received his Ph.D. in Organic Chemistry at the State University of Iowa in 1951. "Doc" has directed the research and development activities associated with pollution abatement and waste disposal for several large corporations before forming Kembro in 1968. These include LOF Glass Co., Owens-Corning Fiberglas, National Distillers and Chemical Corp., and Phillip Morris.

Being a do'er, "Doc" decided to do something about pollution of our lakes, both man-made and natural. Seeing the need for providing the do-it-yourselfer with proper dependable, yet inexpensive equipment to save this valuable resource and sport, "Doc" developed the Venturi principle of aeration and thermal de-stratification known as the GenAIRator.

"Doc's" local friends know him as a German band clarinet player, private pilot, and Civil War buff.

(GenAIRator is the Trademark of Kembro, Incorporated, Box 205, Mequon, Wisconsin 53092).

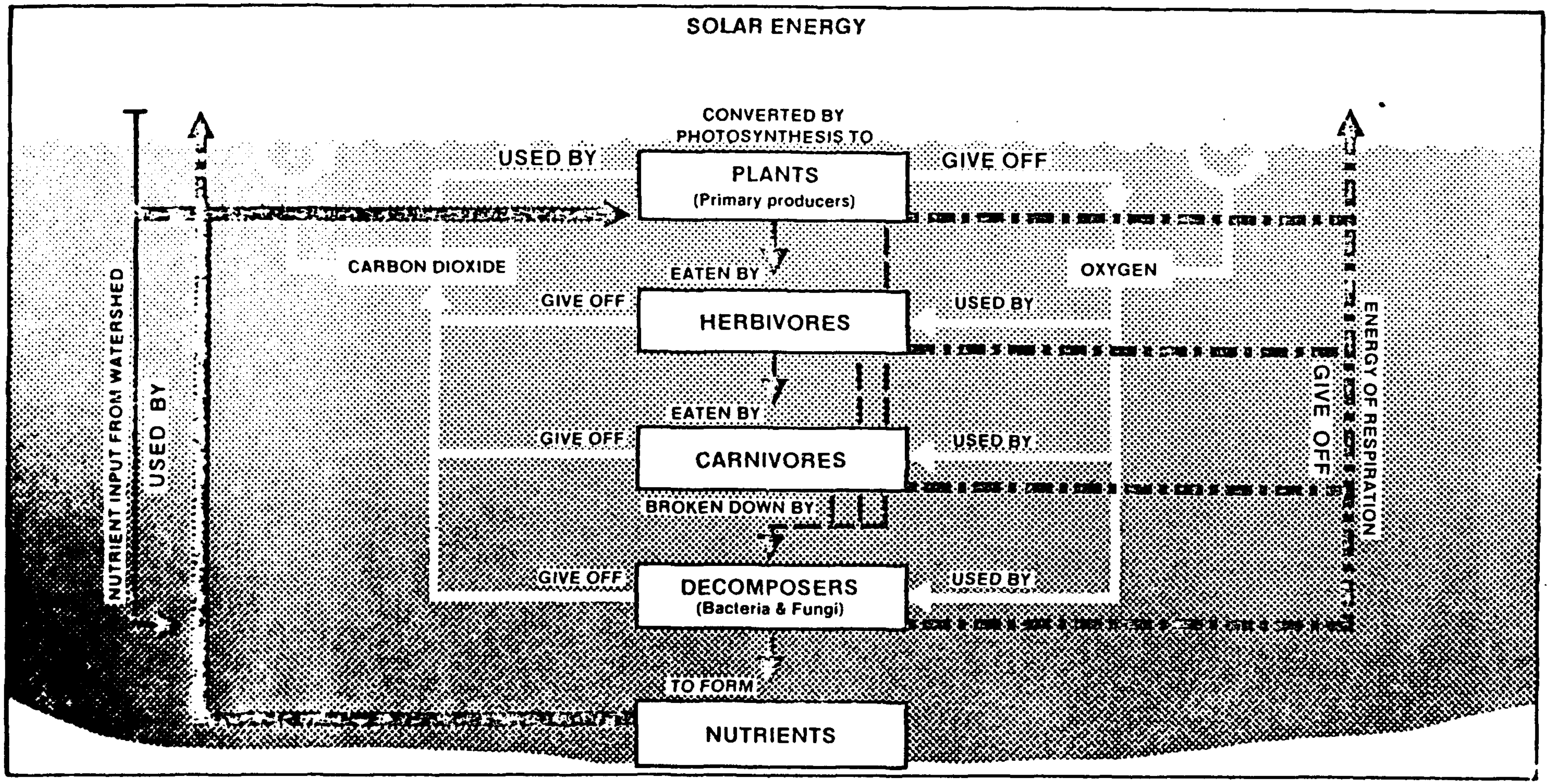
WHO NEEDS HELP?

Lake restoration is now a big item of interest and controversy in America. Pending legislation to grant Federal Funds for the installation of systems to restore the nation's lakes to some condition other than the ones they are in now, seems certain. To those who own lake property and to those many people who use lake property, such a program brings up many questions.

First, we must assume that there is something wrong with the lakes that make some sort of "restoration" necessary. Secondly, we must also assume that if we were given enough money by our government, we could change our sick or dying lakes into something else that we would like better, perhaps lakes like the Indians had when the white man first came. Or maybe like the lakes were when they were first formed 10,000 years ago as the last glacier faded away.

In any event, some lakes are "bad" and we want them to be made "good" and Uncle Sam or somebody else with a lot of tax money is going to fix them for us "free".(?)

WHAT IS A LAKE?



SOME INTERDEPENDENCIES IN A LAKE ECOSYSTEM *The aquatic ecosystem is complex and its components are interrelated. The various life forms depend upon one another for their existence*

Courtesy of Upper Great Lakes Regional Commission

Some general characteristics of lakes — Lakes are more than standing bodies of water. Their physical and chemical characteristics make them ideal homes for an immense variety of organisms and communities of plants and animals. A lake ECOSYSTEM is composed of a community of interacting animals, plants and bacteria, and the physical and chemical environment in which they live. All parts of the ecosystem is composed of a community of interacting animals, plants and bacteria, and the physical and chemical environment in which they live. All parts of the ecosystem mesh in an intricate scheme of interdependence. This drawing indicates the complexity of lakes, and shows that it is not possible to disturb one part of an aquatic ecosystem without affecting numerous other parts.

Nothing is "free" As property owners, if you do get a government project on your lake, you'll lose a great many of your property rights. You don't want that. Tax money spent here will only make inflation worse. What is wrong with the lake anyway? Why the fuss?

WHAT'S "GOOD" AND WHAT'S "BAD"?

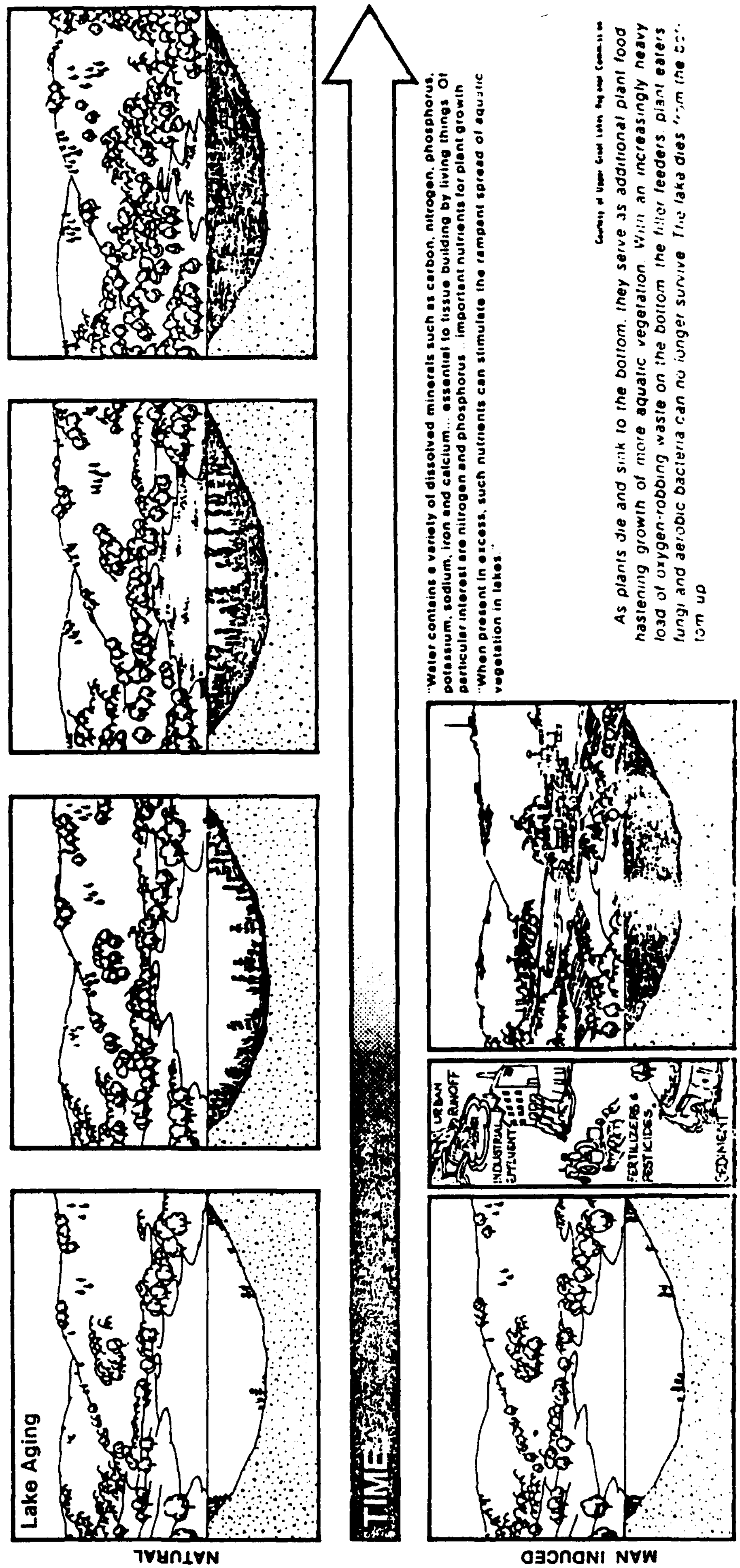
Let's see what makes a lake "bad" that we once found to be "good". Shallow water is the biggest complaint I hear these days. It is the cause of such problems as excessive weed growth in many cases where the lake property owners do not recognize this cause, and where fish freeze out or winter-kill. Such lakes cannot support a population of game fish, because in the winter when the water is covered with ice and snow, there is oxygen depletion and the fish smother to death.

Streams and local rain run-off bringing in mud and silt fill up some lakes. Only dredging will restore such a lake. The soil, sand, gravel, or clay will not go away by itself. One such lake is Lake Kadija in the Medinah Country Club, Medinah, Illinois. Once twelve feet deep, the erosion of Illinois top soil has filled in the lake to the point where one can wade through 90% of this 60 acre manmade impoundment. Such is the fate of thousands of lakes. What happened to Kadija happened to Lake Decature at Decatur, Illinois, Lake Vermillion at Danville, Illinois, and Little Muskego Lake near Milwaukee.

If there is some bottom over 40 feet deep, as in the case of Little Muskego Lake, a good game fishery can be maintained with a little help from the Department of Natural Resources. They drained down the lake and poisoned the trash fish. Upon refilling, they stocked desirable species so that today this should be a great fishing lake, one that we would term "good" Right? Wrong! Now this brings us to the second big complaint — pollution.

IT'S THEIR FAULT!

There are two kinds of pollution. The first, manmade pollution, has received so much attention from activists that we've lost sight of the second kind, natural pollution or eutrophication. Again, many lake property owners, teachers, and students over-



took the natural production of veg table matter from sunlight, air, and water by photosynthesis in green plants and algae as the primary cause of a lake going "bad". If you fish there, you don't like too many weeds growing and rotting on the lake bottom, crowding out the sport fishing, and stinking up the water so badly that often the fish you do catch taste stale and muddy.

Of course, man can speed up the normal death of a lake by pollution of his own making. Anything that fertilizes the algae and weeds speeds up their work of turning the lake into a meadow. Here again, the excessive growth of weeds and algae cause a build-up of decaying organic matter and the stagnant lake is called "bad". This is apart from the dumping of mine wastes, chemicals, fuel oil, and who knows what into a stream or lake that results in a fish-kill. Occasionally, there are toxic substances that kill the fish, but mostly it's *oxygen depletion* that does them in.

WHAT IS LAKE BED AERATION?

"Aeration" is the term we use to mean adding air to the water. Because air contains 22% oxygen, aeration adds oxygen to the water.

Several forms of aeration have been used in the past. Most of these older units are what we call "surface splashers". Various designs of post-mounted or float-mounted electric motor driven pumps or propellers cause fountains of water to splash into the air. These are fine in shallow water such as a fish hatchery. Unfortunately, these various units expose just surface water to the atmosphere. As we shall see later, where the oxygen is really needed in a lake, is at the bottom.

Also, electric wires must be taken to the motors out in the water. Insulation break-downs and shorts into the water can cause shock hazards and heavy power losses, so it's better if electricity can be kept away from the water. These surface units are boating and waterskiing hazards as well.

Lake bed aeration is different since these systems add oxygen to all of the water in the lake, not only to the surface water, but to the water at the bottom of the lake as well. This is very important. Once the lake or pond is full of oxygen near the bottom, new insect larvae, snails, and other fish food can begin to live on the bottom.

All systems that pump water use a lot of electricity for the amount of oxygen they put into the water. It takes much less energy to pump air than water because air weighs a lot less. Therefore, a one fourth horsepower air pump can do the work of a water pump requiring four to six times as much electricity. The exceptions to electricity use are the wind mills. These usually mix very little oxygen into the water, especially on a cold, clear, still, star-lit winter night when everything in the woods freezes tight.

By pumping compressed air out into the lake bed aerator, the rising air bubbles bring the bottom water to the surface where it is exposed to the atmosphere. Large volumes of water thus lose bad gases to the air and pick up even more oxygen while on the surface.

Natural bacteria attack the oil, milk, whey, manure, or whatever, from canning plants, municipal sewage plants, farms, factories, and mills. Bacteria will breath oxygen if it is available. They like this new "banquet" so well that they grow very fast, multiplying rapidly to gigantic numbers, using up all of the dissolved oxygen in the water. There being no oxygen left in the stream, or lake, due to the high *biological oxygen demand* of these bacteria, the fish die. The fish cannot breathe until all of the pollution is "burned up" by the bacteria.

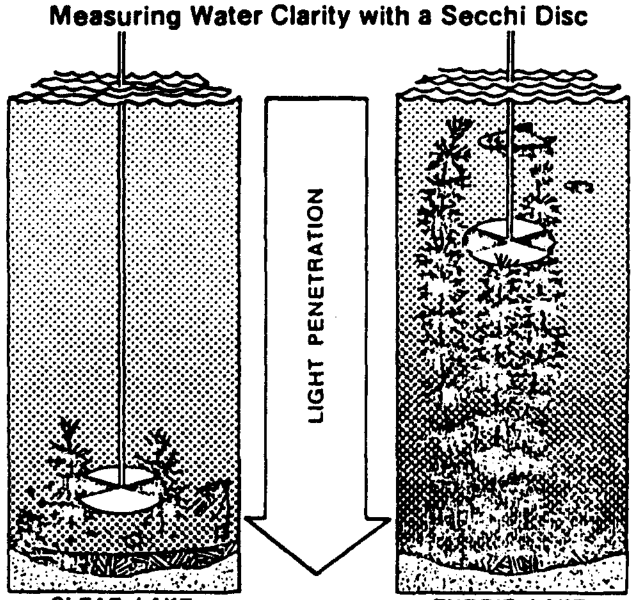
Aeration speeds up this process of oxidizing or "burning up" the pollution. In fact, if there is sufficient aeration, the fish will be able to survive a surprising amount of pollution in a place like a feed lot run-off pond or tertiary sewage treatment lagoon. These are potentially good fishing spots. There is no reason for such places to be "bad", even if there are occasional spills or excessive draw downs.

So "badness" *nearly always* has to be blamed upon decaying vegetation caused by excessive primary production in overly fertilized bodies of water. "Goodness" is fresh, sparkling clear, sweet-smelling water which supports abundant fish life, free from excessive algae and weeds.

Some algae is necessary, being the first step up the fish food ladder. Zooplankton graze on the algae; they cannot manufacture their own food out of light, air and water as the algae do, giving off oxygen in the process. Zooplankton need oxygen to breathe, like most living things. Aeration of the water improves their

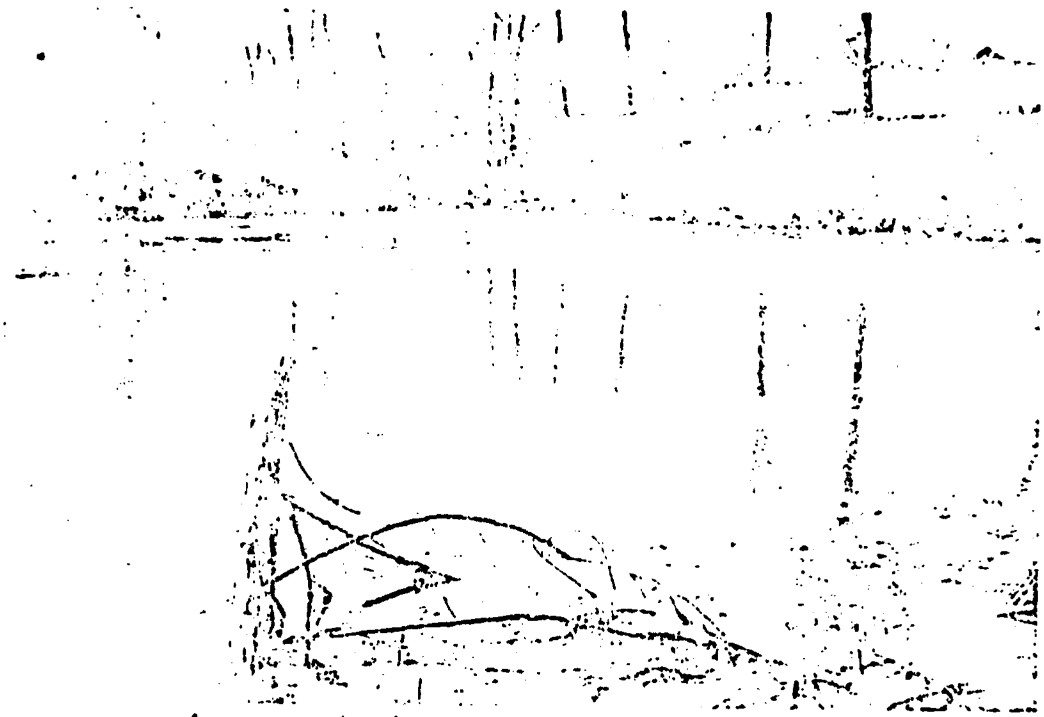
KemDio Incorporated, gratefully acknowledges FISHING FACTS magazine's permission to reprint this article in its entirety as it appeared in the April, 1974, issue, under the title, "AERATION'S AN ANSWER FOR SOME SICK LAKES".

Measuring Water Clarity with a Secchi Disc



Water clarity governs the depth of light penetration in lakes. Periodic testing with a Secchi disc may show seasonal variations in clarity.

Courtesy of Upper Great Lakes Regional Commission



A growing number of property owners and concerned anglers are discovering that scum, algae, and bubbling gases are no longer found only on "the other guy's" lake. Many are finding the problem creeping closer to their own backyard.

environment. Their numbers increase over tenfold when aeration begins. They eat the algae, and the fish eat them.

IT'S A RACE

It's those special bacteria that determine if a lake is "good" or "bad" in North America. Do the bacteria digest the decaying vegetation faster than it's produced? The normal death of a lake over the centuries is for it to fill up with dead plant matter until there is no water left, just weed [illegible]ses, trees, or a [illegible].

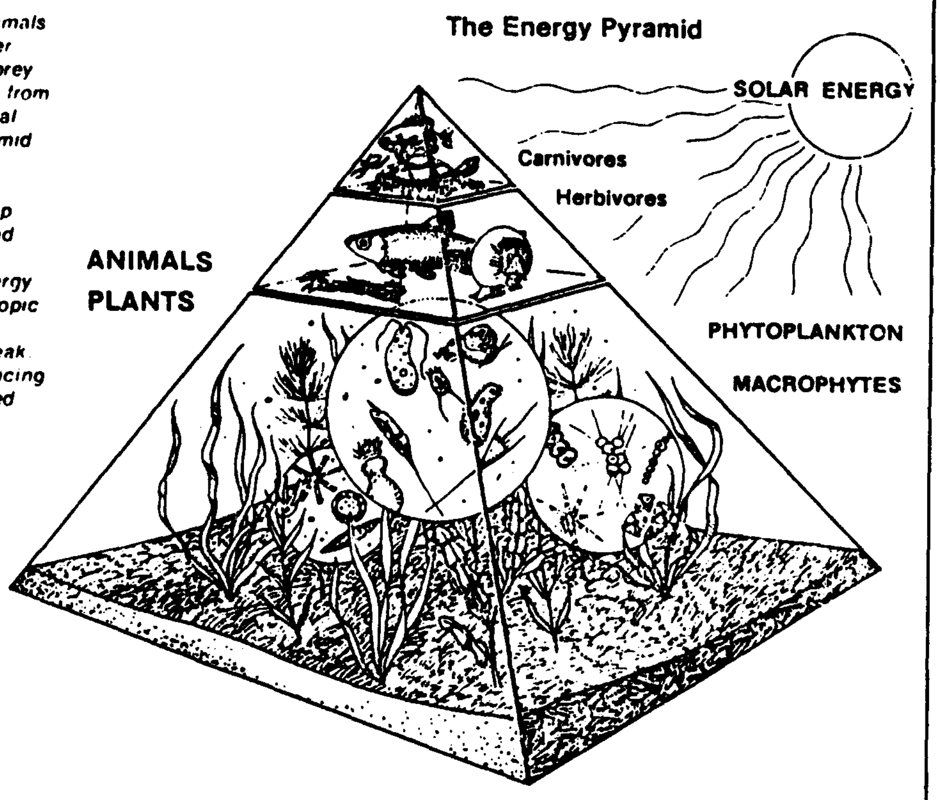
The k[illegible] keeping a lake [illegible] by pr[illegible] lake management [illegible]s to *speed up* the bacterial di[illegible] of dead plant matter and [illegible] *down* the production of new [illegible] matter to the point where the [illegible]teria of decay can keep ahea[illegible]

Lakes that support rapid alg[illegible] plant growth are termed "eutro[illegible]" lakes. Eutrophication comes [illegible] the Greek word for "over-fed" an[illegible] that's just what the plants are [illegible] they tend to grow too fast [illegible] lakes are overly fertile with [illegible] food, the same plant food us[illegible] lawns, gardens, and fields. In [illegible], agricultural run-off is an impo[illegible] source of fertilizer for ponds [illegible] lakes supporting excessive veg[illegible]tion production. The important [illegible]ments employed here are fixed [illegible]gen, potassium, and phosphorus, [illegible] three main plant foods.

Other elements are needed [illegible] growing plants and algae such [illegible] calcium and magnesium, always [illegible] cause of "hardness" in the wat[illegible] Hard water lakes are always proble[illegible] lakes with respect to algae and w[illegible] growth. Carbon dioxide supplies the carbon needed by the plants and is present in the air at 0.03-0.05% concentration. Hard water can hold a lot more carbon dioxide as dissolv[illegible]

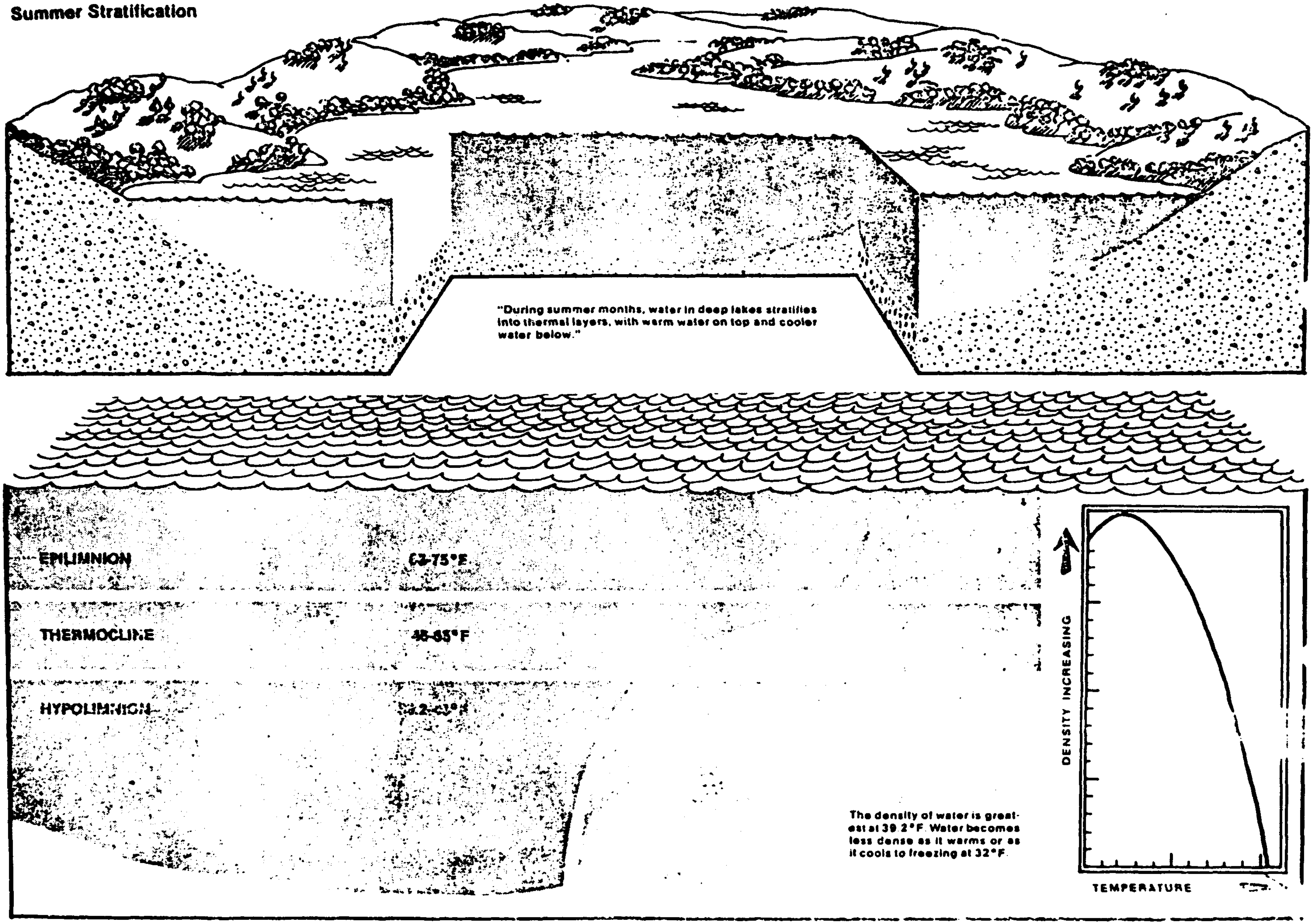
In lakes plants are eaten by animals and animals are eaten by each other. The predator of one species is the prey of another. This process continues from the lowest plant to the highest animal and constitutes the food web or pyramid (also called the food chain).

The fixed amount of energy available to a lake is transferred up through the food web by plants and animals. The "energy pyramid" drawing depicts the transfer of energy in an ecosystem, from the microscopic plants (phytoplankton) to the final consumers, the carnivores, at the peak. These relationships impose a balancing effect even on the most complicated ecosystems.



Courtesy of Upper Great Lakes Regional Commission

Summer Stratification



The carbon dioxide at the surface blows away in the wind.

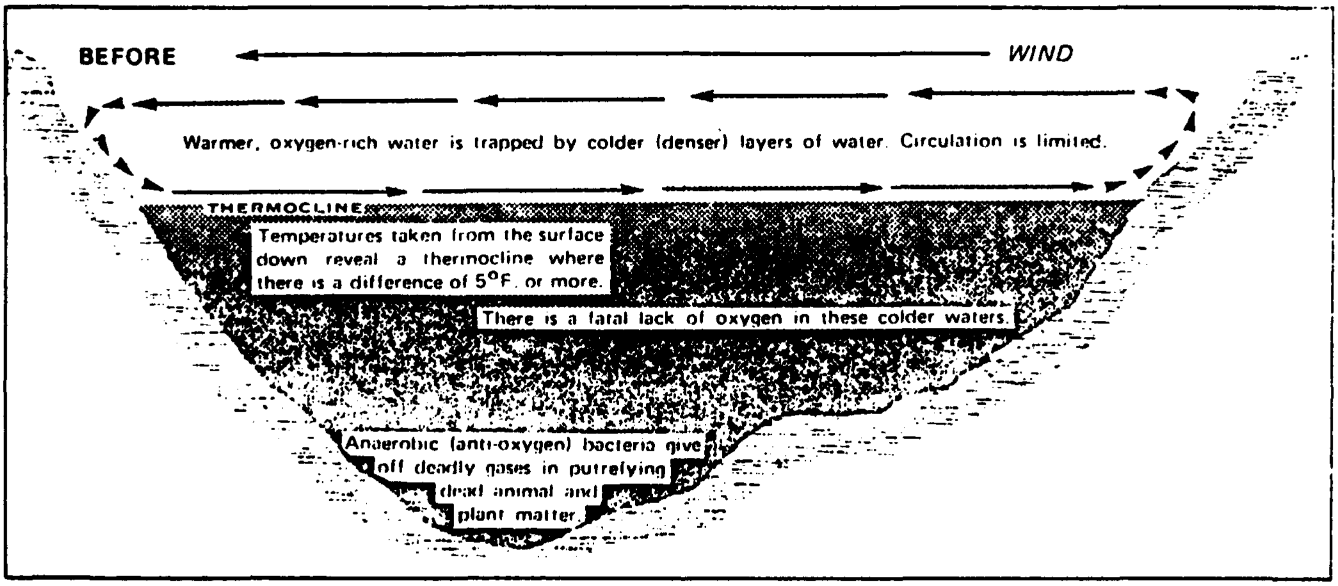
Another dissolved gas coming from decaying plant matter in a "bad" lake bottom is deadly hydrogen sulfide. This has the smell of rotten eggs and is highly toxic to fish. If oxygen is present in the water, no hydrogen sulfide is formed. Where the lake is "bad", aeration causes more phase distribution and the smell of rotten eggs is strong above the aerator for the first several days. Soon the lake is "good" again. Most of the off-flavors in fish flesh taken from a "bad" lake are due to the presence of sulfur compounds coming from this hydrogen sulfide. We note that even small amounts of dissolved oxygen in the water at the lake bottom are toxic to the sulfate-reducing bacteria responsible for the hydrogen sulfide. *Aeration makes the fish taste better*, so now this lake is "good".

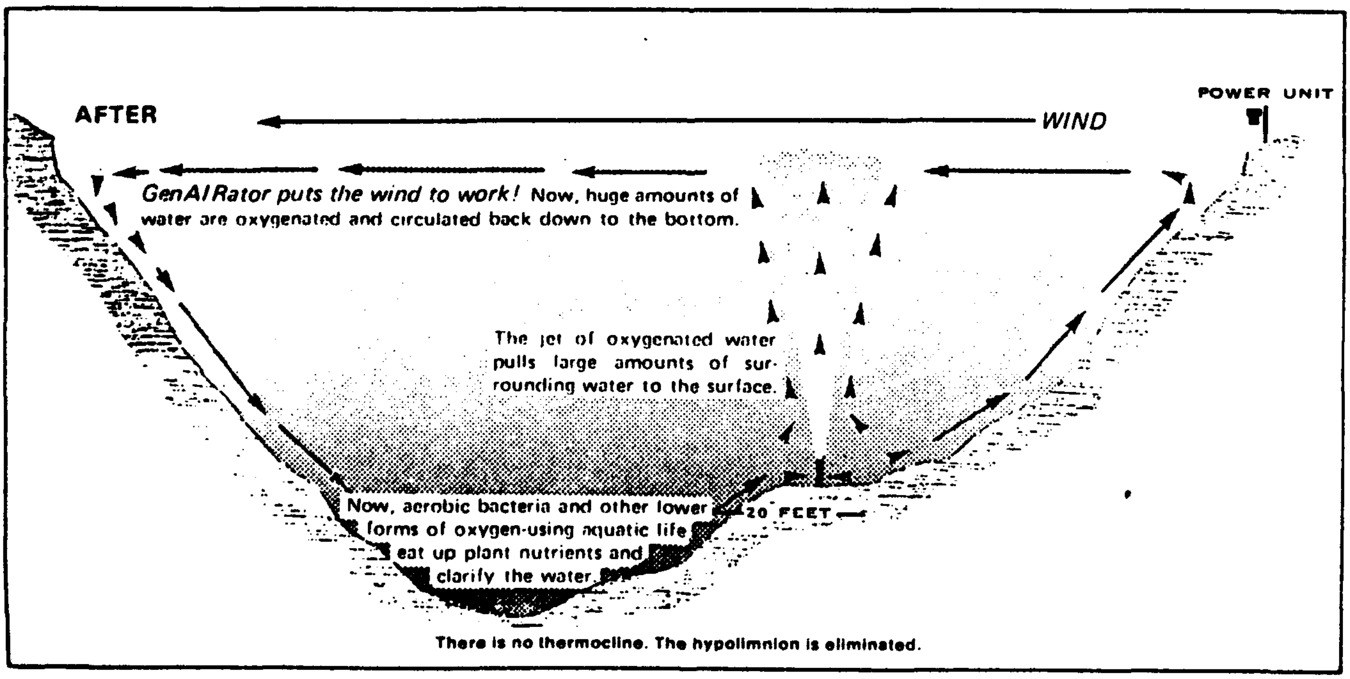
WE WANT BACTERIA ON OUR SIDE

There are two kinds of bacteria all around us: those that need oxygen to live, called aerobic bacteria, and those th[illegible] and grow in [illegible] absence [illegible] [illegible]gen, called anae[illegible] bacteria. [illegible] are different in an[illegible] er way.

Aerobic bacteria grow and eat [illegible] to 30 times faster than anaero[illegible] bacteria. We scientists like to say [illegible] this way: "Aerobic systems [illegible] characterized by high pE values an[illegible] high energy availability following introduction of organic matter, wh[illegible] anaerobic systems are characteri[illegible] by low pE and redox values and l[illegible] energy availability."

Here, pE means electron activ[illegible]





carbonate and bicarbonate than soft water. This is the reason hard water lakes are troublesome.

Some lower forms of plant life such as blue-green algae require other substances such as vitamin B-12 in the water since they apparently cannot manufacture their own. The B-12 comes from air born pollen and from green algae, bacteria, and fungi in the water. In return, the blue-green algae give off substances which are poisonous to other plants so as to eliminate competition from other species for the food supply and sunlight. Sometimes these poisons are so toxic from the blue-green algae species that they kill birds, fish, and even livestock within five minutes after drinking the infected water!

We have discussed fertilizers for algae and weeds, but other factors also determine how fast vegetable matter is produced. Warmer water causes plants to grow faster. Those terrible blue-green algae, the worst kind of all, like warm surface water for their foul and often toxic habitat.

More sunlight means more primary production by photosynthesis in the chlorophyll of algae and weeds. This continues as long as the food supply holds out. When one of the nutrients is exhausted from the water, production stops for the most part. When production stops, the bacteria have some time to catch up with their digestion of dead algae and plant matter.

So, limiting the nutrients limits algae and weeds the natural way. Now how can bubbling air through the water and exposing it to the atmosphere limit plant nutrients? To answer this we will take a close look at what happens to these nutrients in a lake when we aerate it.

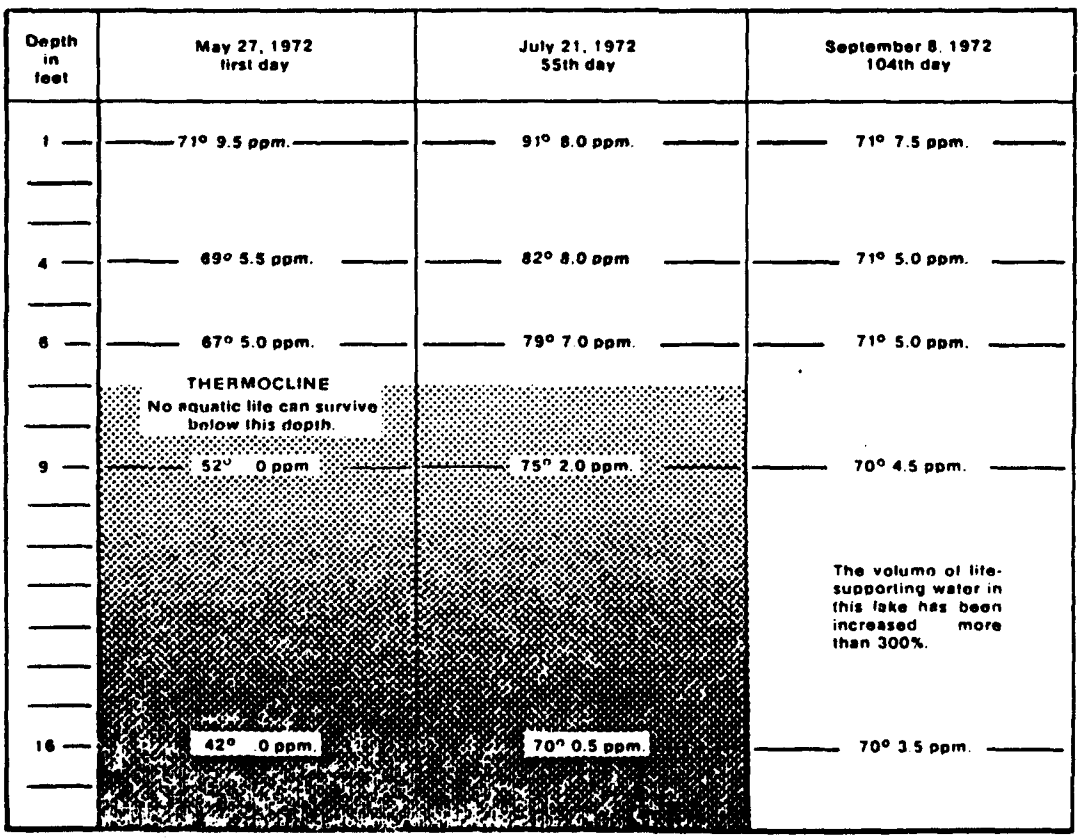
STARVING SLOWS THEM DOWN

Plants need iron for photosynthesis. Plants need phosphorus for their enzymes. Dissolved oxygen in the water makes all iron oxidize to the ferric (or plus three) state from the ferrous (or plus two) state. Ferric phosphate is not soluble in water. There goes the iron and some of the phosphorus *out* of the ecosystem, *precipitated out into the bottom mud* as the insoluble iron phosphates. They are no longer available for plant nutrition and growth.

Plants need manganese for chlorophyll production. Dissolved oxygen ... the manganous ... in the ... to manganese d... and in...ble manganic (or ... three) pho...phate *which settles* ... *bottom*. There goes the manga... and some more of the phospha...

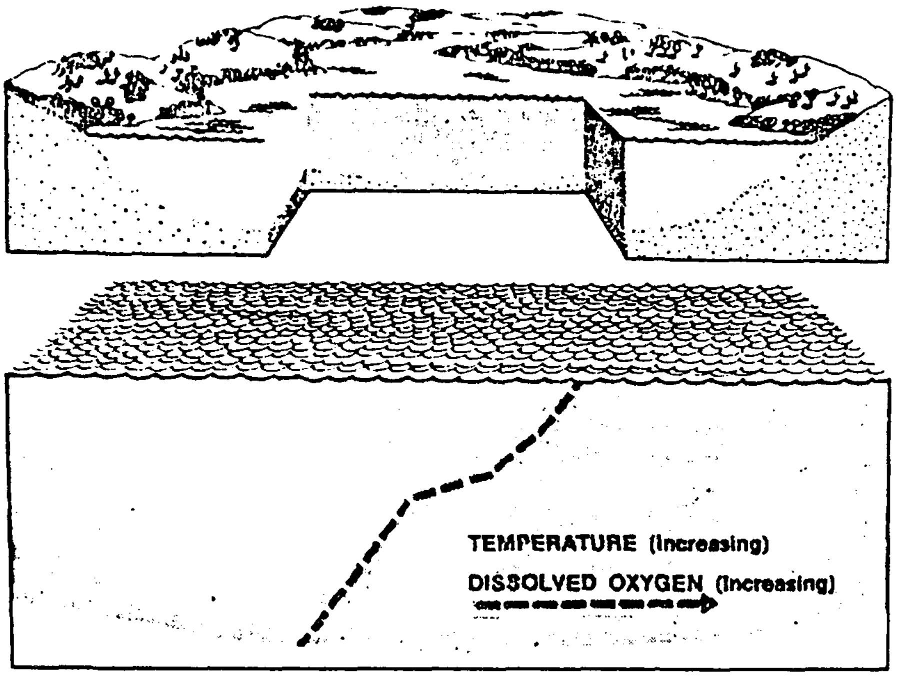
Plants need nitrogen in a fixe... water soluble *form* (not as the ... nitrogen that makes up 3/4ths of ... atmosphere.) Plants such as al... need nitrates, nitrites, and ammo... *The fixed nitrogen form most* ... found in the water, produced ... *decaying vegetation, is ammo*... When we aerate, we actually b... the ammonia *right out of the la*... mechanically. The water and air ... change the ammonia, but the ... moves away in the wind. There go... the nitrogen by "phase distribution"

Plants need carbon dioxide a... water to turn into sugar, using s... light by photosynthesis. We simp... say six molecules of water and six ... carbon dioxide unite to form on... molecule of glucose and six mole... cules of oxygen in the chloroplast. While not strictly the story, it's th... result and you can see oxygen is put into the water by this process. Glu... cose is the plant's building block fo... cellulose. What does aeration do about this? Phase distribution ag...



Report On A GenAIRator Installation — This natural seven acre glacial kettle lake was found to be in an advanced state of eutrophication. The bottom was spongy peat, many feet deep, with more peat constantly being formed from a heavy load of oxygen-using organic matter. Readings were taken at depths of one, four, six, nine and 16 feet throughout the lake, then averaged to show the results below. Temperatures are Fahrenheit. The ppm readings indicate parts per million of oxygen dissolved in the water. Lake Readings Were Taken On May 27, 1972. The GenAIRator Was Installed At A Depth of 18 Feet That Same Day.

Oxygen Distribution in a Stratified Lake



Courtesy of Upper Great Lakes Regional Commission

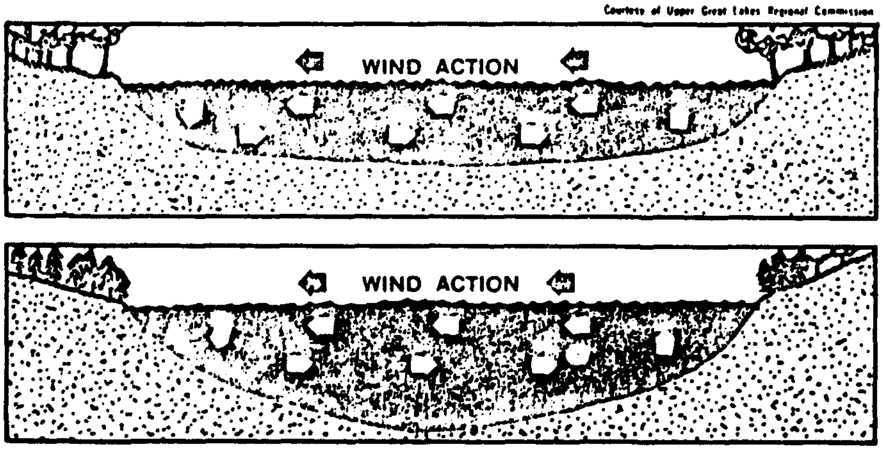
*Oxygen distribution in a stratified lake — Note that oxygen has been depleted in the hypolimnion and fish are absent. The thermocline acts as a barrier to mixing, and prevents aeration of the hypolimnion. Furthermore, because of the depth and lack of sunlight, the hypolimnion does not benefit from photosynthetic oxygen production. The lake is reoxygenated during the spring and fall overturn and then fish may inhabit the deeper waters.**

**(Unless they are killed by the poisonous/methane, ammonia, hydrogen sulfide/bottom water as it rises to the surface when the oxygen-rich surface water descends.) Footnote by: Dr. Mervin M. Browne.*

which is important to the scientist. It all boils down to this: In one year, aerobic bacteria will digest and change into carbon dioxide and water the amount of dead vegetation that anaerobic bacteria take 30 years to digest! So, *if oxygen is present at the lake bed*, called the benthic zone, dead weeds and peat do not accumulate as bottom muck. Such muck is quickly eaten by our aerobic friends, not slowly chewed upon by anaerobics who fall behind in their work, and lose the race, allowing the pretty pond or lake to go "bad", filling up with peat. That's how coal was formed eons ago. It's the natural death of a lake, just as it's natural for aerobes to eat up dead vegetation and algae and keep it "good". Thus aeration and destratification keep these aerobic bacteria on the job by assuring them a constant supply of oxygen.

Summer mixing of lakes by wind — Shallow lakes are kept well mixed by wind action. Winds mix only a portion of deeper lakes.

Courtesy of Upper Great Lakes Regional Commission



In really "bad" lakes, the b... can be helped tremendously if the excessive growth of aquatic weeds is removed by mechanical harvesting. There may be so much plant food in the water that unsightly weed growth results. Harvesting these weeds not only removes much nutrient physically, but takes a big load off our aerobic friends. The removed weeds, applied to fields as green manure, are an agricultural asset in*stead* of an aquatic liability.

Occasionally, chemicals are applied to slow down production. This must be considered an emergency shock treatment for the lake of short term benefit. It gives the bacteria some extra time to catch up since primary production is temporarily halted. Compared to aeration alone, chemicals are an expensive last resort and other forms of wild life generally suffer a set-back following any chemical application. The dangers require an expert be used to balance the risks of application. *Repeated* use of chemical toxicants can only be harmful, as this is an unnatural introduction into the ecosystem even though sometimes necessary, especially in the warm South where hydrilla, water hyacinths, and water lilies get out of control.

HOT OR COLD

Speaking of the warm South where primary production goes on all year 'round, you would think that the bacteria could never catch up and dead vegetation would be mountainous. Such is not the case, obviously. The reason is that our *friendly* bacteria digest the dead plants much faster at warmer temperatures. (For example, glucose from cellulose is eaten only one tenth as fast at 45°F. as at 85°F by aerobic bacteria.)

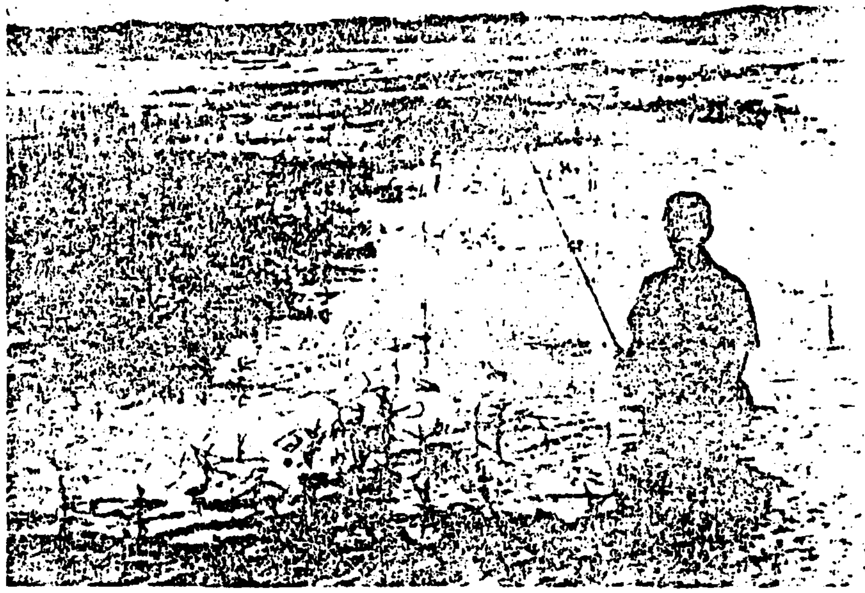
Reversing the photosynthesis equations: six molecules of oxygen are combined by the bacteria with one glucose molecule to form six molecules of carbon dioxide gas and six molecules of water. All of this talk about molecules may sound unrealistic, so let's put it as: 18 pounds of cellulose combines with 19 pounds of oxygen to yield 26 pounds of carbon dioxide and 11 pounds of water. The rate of these reactions is predicted at different temperatures by biologists using the famous Arrhenius equation, which students usually refer to jokingly as the "er-

roneous" equation. Bacteria have strict temperature limitations. Fortunately, there are thousands of kinds of bacteria and some like it hot while others like it cold.

Up north in New England, Michigan, Wisconsin, Minnesota, and in the mountains and Canada, the lakes are covered with ice half of the year. Algae and plants grow only during the warm "open" months. Why can't the bacteria keep up with plant production in these areas? Why so much peat bog and muck accumulation in the north country?

If we look at a "bad" lake in New York State, we see a typical glacial lake dying. The winter months find the bottom at 39.5°F. and no oxygen – water being most dense at this temperature. The ice seals off the lake surface so that no atmospheric oxygen can get into the water all winter. When the ice melts out in the late spring, the cold heavy water stays at the bottom even while the sun and air warm the surface water up to above 80°F. This lighter weight, warmer water stays on the surface until cold autumn nights chill it again six months later. We call the warm upper layer the "epilimnion" and the cold, dead, bottom layer the "hypolimnion". We put food in refrigerators to keep bacteria from growing in it, called "spoiling". Our New York State lake bottom is refrigerated, seldom getting over 55°F. in sixty-five feet of water. It still has no oxygen, but even anerobic bacteria can't digest the dead plant life and algae raining down from above at those low temperatures.

Some experimenters have tried adding oxygen to this cold hypolimnion as in Lake Waccabuc in New York. All attempts to improve a "bad" lake by oxygenation of only the cold bottom layers of water should be reexamined with a more practical analysis of the problem to be solved in mind. High power costs and expensive equipment have yielded only inconclusive results. If we want our friendly aerobic bacteria to eat up the bottom debris in a hurry, we have to warm them up as well as give them oxygen.



Vegetation can offer cover and concealment for bait fish and game fish alike. However, there are times when Mother Nature may need a helping hand to prevent the needless and premature death of a lake

THE SIMPLE SOLUTION

A northern lake may be "saved" by the installation of the lake bed aerator that oxygenates the water at the bottom, and destroys the hypolimnion by low cost, low-powered, continuous destratification. Bottom temperatures come up to 60-65°F. while the mixing of the cooler bottom water with the surface water brings down the surface water temperatures to 70-75°F. during June. On a windy day, or during a Cold Front passage, winds of 35 to 40 miles per hour, mix up the whole lake. We see 72°F. from top to bottom and plenty of dissolved oxygen also — over 7 parts per million — enough for game fish as well as for our *friendly* aerobes. They are eating the bottom debris at four times the rate they would in an aerated hypolimnion and 60 to 70 times faster than if we had left the lake to its own natural death. *If man has added his own pollution*, lake bed aeration restoration results are even more dramatic.

Above the Lake Bed Aerator in the winter, a hole in the ice remains open, 20 to 40 feet in diameter. The lake waters are not sealed off from light and the atmosphere by ice. Dissolved oxygen levels remain high all winter. There are no distressed fish and our bacteria keep on slowly eating. This is quite a change from normal winters. The ice goes out 3 weeks sooner, too. This opens up the lake to the atmosphere sooner, and the results are apparent. Spawns are more successful. Soon the "bad" lake is once again a "good" lake and it didn't take an act of Congress or a "megabuck" program to get the job done. Even the individual property owner can install this lake bed aerator system in less than two hours with a friend, maybe a six-pack, a screw driver, and a pair of pliers.

When installed and running, the lake bed aerator makes an unbelieveably active fishing hole according to some Illinois State Fishery Biologists and many GenAIRator owners. The unit is designed to run day and night all year 'round without maintenance. Don't worry about the effects of mixing a "nutrient-rich hypolimnion water" with surface water — there isn't any hypolimnion any more, just "good" fishing water.

Typical Airator Installations

D= Deepwater Units = Regular (Standa